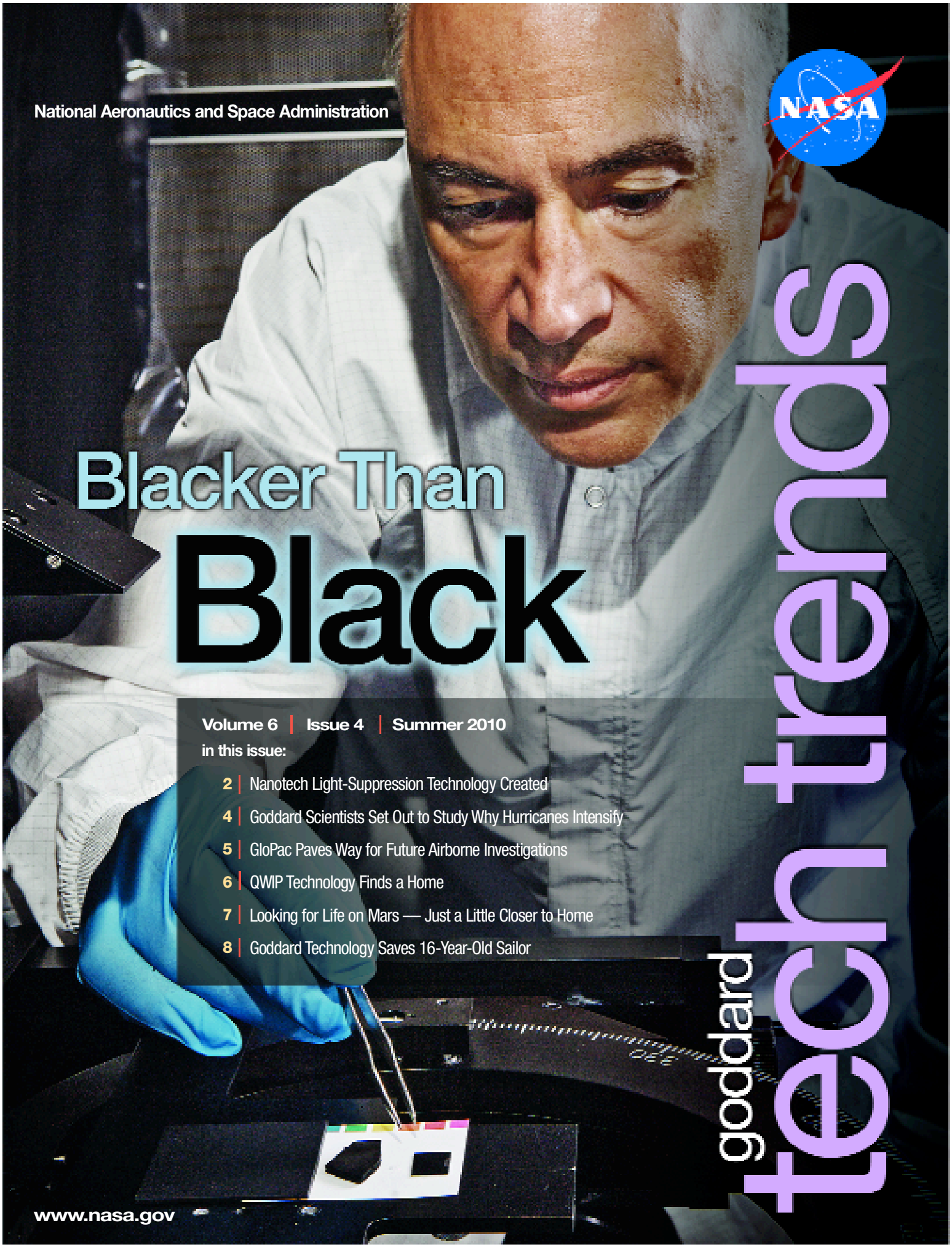

National Aeronautics and Space Administration

Blacker Than Black

goddard tech trends

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Blacker Than Black

Goddard Optics Engineer Develops Light-Suppression Nanotechnology

Light has a funny way of ricocheting off instrument components and contaminating measurements, but a team of Goddard technologists has created a blacker-than-pitch material that absorbs stray light, potentially providing orders-of-magnitude improvement over current light-suppression technology.

The nanotech-based material now being developed by a team of 10 Goddard technologists is a thin coating of multi-walled carbon nanotubes packed vertically much like a shag rug. The tiny gaps between the tubes collect and trap background light to prevent it from reflecting off surfaces and interfering with the light that scientists actually want to measure. So far, the Goddard team has applied the coating to an instrument component to assess its durability for Earth observations and another team is considering its use on a proposed astrophysics mission.

"This is a technology that might provide a lot of payback," said engineer Leroy Sparr, who is helping develop the Ocean Radiometer for Carbon Assessment (ORCA), a next-generation instrument that would measure marine photosynthesis (*Goddard Tech Trends*, Summer 2008, Page 6). Reflectance tests show that the carbon nanotubes absorb more than 99.5 percent of the light that hits them. "It's about 10 times better than black paint" typically used by instrument designers to suppress errant light, he said.

Space Qualification Expected

In addition to conducting reflectance tests, the technology-development team led by Principal Investigator John Hagopian plans to conduct vibration and acoustics tests over the coming weeks to further qualify the coating's use in space. In fact, Hagopian hopes to achieve space qualification by the end of summer, he said.

Hagopian's team began working on the technology in 2007 in part with Goddard R&D funds. Unbeknownst to the group, the New York-based Rensselaer Polytechnic Institute also had initiated a similar effort and announced in 2008 that its researchers had developed the darkest carbon nanotube-based material ever made — more than three times darker than the previous record. "Our material isn't quite as dark as theirs," Hagopian said. "But what we're developing is 10 times blacker than current NASA paints that exponentially suppress system stray light. It also will be robust for space applications."

That is an important distinction, said Carl Stahle, assistant chief for technology for the Instrument Systems and Technology Division. Not all technology can be used in space because of the harsh environmental conditions encountered there. "That's the real strength of Goddard," Stahle said. "We have to find ways to apply new technology and fly it on our instruments."

The breakthrough was the discovery of a highly adhesive underlayer material upon which to grow the carbon nanotubes, which are just a few tens of nanometers in diameter. To grow carbon nanotubes, materials scientists typically apply a catalyst layer of iron to an underlayer on the silicon substrate. They then heat the material in an oven to about 750° C (1,382° F). While heating, the material is bathed in carbon-containing feedstock gas.

Stephanie Getty, the materials scientist on Hagopian's team, varied the underlayer as well as the thickness of the catalyst materials to create carbon nanotubes that not only absorb light, but also remain fixed to the material upon which they are grown. As a result, they are more durable and less likely to scratch off. The team also has grown durable nanotube coatings on titanium, a better structural material for space use. The team now is fine-tuning production techniques to assure consistent quality and light-suppression capabilities, Hagopian said.

Should the team prove the material's suitability in space, the material will provide real benefits to instrument developers, Hagopian added. Currently, instrument developers apply black paint to baffles and other components to reduce stray light. Because the coating is more effective than paint, instrument developers could grow the carbon nanotubes on the components themselves, thereby simplifying instrument designs because fewer

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About The Cover:

Principal Investigator John Hagopian is leading a team of Goddard technologists now developing a nanotube-based material that is 10 times blacker than paint used by instrument designers to suppress errant light. The sample on the left is black paint; the sample on the right is the new nanotube material. Among its many benefits, the technology would allow scientists to gather hard-to-obtain measurements because of limitations in existing light-suppression techniques or to gather information about objects in high-contrast areas, including planets in orbit around other stars.

Photo Credit: Chris Gunn

The team now developing a nanotube-based technology that promises to be more effective than current light-suppression techniques includes (from left to right): Patrick Roman, Alex Maldonado, Jim Butler, Stephanie Getty, Cleophus Hunt, Mary Li, John Hagopian, and Georgi Georgiev. Not pictured are Greg Hidobro and Manuel Quijada.

baffles would be required. To accommodate larger components, the team now is installing a six-inch furnace to grow nanotubes on components measuring up to five inches in diameter. And under a NASA Innovation Fund award, the team also is developing a separate technique to create sheets of nanotubes that could be applied to larger, non-conforming surfaces.

In addition to simplifying instrument design, the technology would allow scientists to gather hard-to-obtain measurements because of limitations in existing light-suppression techniques or to gather information about objects in high-contrast areas, including planets in orbit around other stars, Hagopian said. Currently, the Goddard team advancing technologies for the proposed Laser Interferometer Space Antenna (LISA) mission, which will measure gravitational waves should NASA select it for development, is considering its use, said Jeff Livas, a LISA scientist.

The ORCA team, which is fabricating and aligning an instrument prototype with support from the NASA Instrument Incubator Program, is the first to actually apply and test the technology. The instrument is the front-runner for the proposed Aerosol/Cloud/Ecosystems (ACE) mission and requires robust light-suppression technologies because more than 90 percent of the light gathered by the instrument comes from the atmosphere. Therefore, the team is looking for a technique to suppress the light so that it doesn't contaminate the faint signal the team needs to retrieve. "It's been an issue with all the (ocean sensors) we've flown so far," said ORCA Principal Investigator Chuck McClain.

Working with the ORCA team, Hagopian's group grew the coating on a slit, the conduit through which all light will pass on ORCA. "Having an efficient absorber is critical and the nanotubes could provide the solution," McClain said. "Right now, it looks promising," Sparr added. "If they can continue advancing the technology so that it can be applied to other spacecraft components, it could be a very important development for NASA." ◆

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SPECIAL REPORT

Goddard Reasserts Leadership in Airborne Instrumentation

A few years ago, Goddard set its sights on reinvigorating its airborne instrument program — a research area in which it had always excelled — and, if this year is any indication, the investment appears to be paying off.

Goddard Earth scientists are leading NASA's IceBridge campaign, the largest airborne survey NASA has ever flown over Earth's polar regions. They are playing prominent roles in four of the five new Earth Venture-1 missions announced a few weeks ago, bringing in nearly $17 million in direct new business. And they were instrumental in demonstrating the value of the Agency's new unmanned research aircraft — the Global Hawk. In fact, Center scientists have developed about a dozen airborne instruments and currently are developing 12 more.

Aircraft missions fulfill an important research niche, said Bob Connerton, chief engineer for Goddard's Earth Sciences Division. Scientists use these platforms to test new technologies, calibrate and validate spacecraft measurements, and carry out critical science investigations. "They really complement our space missions," he added, "and represent a great opportunity for us."

In this issue, Goddard Tech Trends highlights a few of those successes and their significance to the Center.

Riders on the Storm

Goddard Scientists Set Out to Study How Hurricanes Intensify

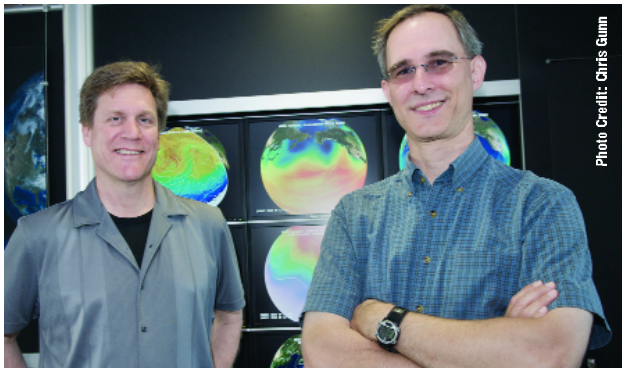
How many times have emergency rescue personnel evacuated people living along the coastline only for a potentially catastrophic hurricane to fizzle out hours before it is supposed to make landfall?

Two NASA-funded airborne missions involving several Goddard Earth scientists are aimed at ultimately preventing those unnecessary and costly evacuations, which by some estimates would save $3 billion in a typical hurricane season. Both the Genesis and Rapid Intensification Processes (GRIP) experiment and the Goddard-led Hurricane and Severe Storm Sentinel (HS3) are expected to enhance scientists' understanding of how tropical storms form and, more importantly, how they develop into major hurricanes.

"The most important factor in whether residents will evacuate is the strength of the storm," said Principal Investigator Scott Braun, who is leading the $30-million HS3 mission, one of five selected under NASA's new Earth Venture program. (Of that $30 million, Goddard will directly receive about $8 million.) "While forecasters have made great progress accurately tracking hurricanes, they've made only small improvements in their ability to predict intensity."

The quest to improve scientists' understanding begins with GRIP on August 15. For six weeks, NASA will deploy two instrument-packed piloted aircraft, the DC-8 and the WB 57, over areas of interest in the Atlantic Ocean to gather data within and in the vicinity of tropical-storm systems. Should conditions suggest a hurricane forming or intensifying, scientists then will dispatch the Global Hawk from its base at the Dryden Research Facility for an extended investigation of conditions.

The Global Hawk is a new addition to NASA's fleet of research aircraft (*Goddard Tech Trends*, Summer 2009, Page 4). The unmanned aircraft flies at up to 65,000 feet — nearly twice as high as a regular commercial airliner — for as long as 30 hours.



Goddard scientists Paul Newman (left) and Scott Braun (right) are leading a $30-million airborne mission to determine how severe storms evolve into hurricanes.

One of the four instruments flying on the Global Hawk is the High-Altitude Imaging Wind and Rain Profiler (HIWRAP), a dual-frequency radar that Goddard Principal Investigator Gerald Heymsfield developed in part with Internal Research and Development (IRAD) program funding. The solid-state instrument — designed specifically for use on unpiloted high-altitude aircraft — will measure horizontal winds and precipitation. HIWRAP also is expected to provide prelaunch simulation data for the Global Precipitation Mission set to launch in 2013.

'GRIP on Steroids'

The investigation continues under HS3. "GRIP really sets the stage for us," said Braun, who will be assisted by Deputy Principal Investigator Paul Newman, who managed the maiden flight of the Global Hawk in April (see related story, page 5). "What's not known is why some storms form and others don't. With HS3, which essentially is GRIP on steroids, we can target specific periods in the life cycle of a storm."

Two Global Hawk aircraft will carry out one-month-long missions during the Atlantic hurricane season beginning

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with a demonstration flight next year. Full science operations with the mission's suite of seven instruments are scheduled to begin the following year and run through 2014. In essence, HS3 will give scientists something they've never had before — a sustained look at storms as they evolve over an extended period of time.

To get a complete picture of developing hurricanes, one aircraft will carry four instruments that study environmental conditions surrounding the storm, including the Cloud Physics Lidar and the Tropospheric Wind Lidar Technology Experiment developed with IRAD funds by Goddard scientists Matt McGill and Bruce Gentry, respectively. The National Oceanic and Atmospheric Administration and the University of Wisconsin are providing the other two instruments.

The second aircraft will carry Heymsfield's HIWRAP and two other instruments provided by the Marshall Space Flight Center and Jet Propulsion Laboratory. These instruments will measure conditions within the storms from a vantage point directly above the hurricane vortex. To accommodate the mission, NASA is building a Global Hawk operations center at the Wallops Flight Facility where pilots will remotely control the aircraft and scientists will command their instruments and receive data in real time. The Agency also is expected to develop a mobile operations center so that the aircraft can deploy virtually anywhere.

Other Venture-Class Missions

In addition to HS3, NASA selected four other new Venture-class missions. McGill, Ken Pickering, and Rolfe Reichle are providing instruments and science support for three. "All in all, Goddard did well with this solicitation," said Bob Connerton, chief engineer for Goddard's Earth Sciences Division. "Hopefully this is just the start." ◆

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GloPac Lays Foundation for Future Airborne Missions

Global Hawk Pacific (GloPac) paved the way for the two missions aimed at understanding why hurricanes intensify. "There is no doubt in my mind," said Goddard scientist Matt McGill, who flew his Cloud Physics Lidar on the maiden science flight of the unpiloted vehicle. "It proved that these missions were possible and would yield valuable data."

GloPac, co-managed by Goddard scientist Paul Newman who also is serving as the deputy principal investigator on the Hurricane and Severe Storm Sentinel (HS3) mission, occurred in April. It included four separate long-duration flights over the Pacific and Arctic regions to explore trace gases, aerosols, and atmospheric dynamics and test the aircraft's duration, altitude, and connectivity with science payloads. "This flight was quite successful," said Newman, who shared management duties with David Fahey, a scientist with the National Oceanic and Atmospheric Administration.

The primary purpose was gathering data to validate measurements by Aura, an A-train satellite that Goddard developed to study Earth's ozone, air quality, and climate (*Goddard Tech Trends*, Summer 2009, Page 4). However, it also collected data showing the breakup of the polar vortex, a large-scale cyclone in the upper troposphere and lower stratosphere, and observed dust plumes that originated from China's Gobi Desert and then traveled across the Pacific into California, Newman said. The observations confirmed computer models that indicated the dust would appear exactly where it was observed.

The Global Hawk unmanned vehicle made its maiden scientific flight in April, proving it was a viable platform for high-altitude, long-duration missions.

Just as important, the maiden flight established protocols and procedures for integrating science instruments and flying an unpiloted vehicle remotely from an operations center at Dryden Flight Research Center, reducing risk for future Global Hawk missions, Newman said.

"The GloPac mission showed that the Global Hawk aircraft is a revolutionary tool for Earth science research," Newman said. "The Global Hawk has now proven to be a science platform that can fly to altitudes of 65,000 feet for long-duration flights approaching 30 hours." ◆

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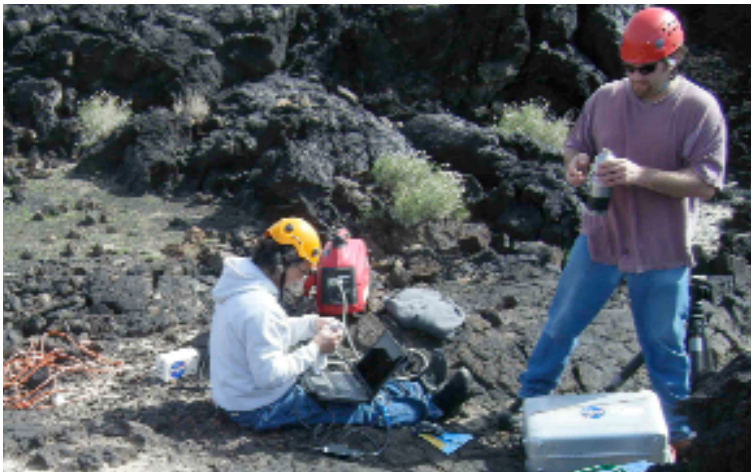
QWIP Technology Finds a Home

Infrared Detector Cleared to Fly on Landsat Follow-On Mission

An infrared-detector technology that Principal Investigator Murzy Jhabvala developed over nearly two decades will debut on a Goddard-developed instrument that will help states monitor water consumption — an important capability in the West where precipitation is sparse and water rights are allocated.

The Quantum Well Infrared Photodetector (QWIP), which Jhabvala and his team qualified for actual spaceflight last August, is being integrated into Goddard's Thermal Infrared Sensor (TIRS) — a late addition to the Landsat Data Continuity Mission (LDCM) scheduled to launch in 2012. TIRS, a 286-kg (630-lb.) two-channel far-infrared imager, will provide surface-temperature data used operationally to monitor water consumption on a field-by-field basis in the West.



Goddard technologist Murzy Jhabvala (seated) and USGS cave biologist Jut Wynne are testing a new detector system in the Mojave Desert that the pair hopes could one day find caves on Mars.

It is the first spaceflight instrument to use QWIP; however, Jhabvala believes the detector technology also is suitable for other potential missions.

TIRS instrument developers selected the QWIP technology because it could easily meet the instrument's performance requirements and production schedule, Jhabvala said, adding that he and his team began working on the detector system in July 2008 after instrument developers realized that another detector technology selected for TIRS would not be ready. "We had a short fuse. That's why the technology was selected," Jhabvala said. "We had little more than a year to build the entire focal plane — starting from scratch."

With various Goddard and NASA R&D funding sources, Jhabvala had matured the technology and had even created years earlier a one-million-pixel array that could sense a range of longer wavelength bands — more robust than the TIRS requirement of 10.5 to 12.5 micrometers. In addition to having the technology already at hand, QWIP technology offered another significant advantage: As technology goes, it is relatively easy to build.

The detector is fabricated on a Gallium Arsenide (GaAs) semiconductor wafer, layered with more than 50 coats of detector material. The layers act as quantum wells, which trap photons and convert them to electrons — the fundamental particles that carry an electric current — and only light with a specific energy can release them.

If the light with the correct energy lands in one of the array's quantum wells, the freed electron flows through a separate readout chip attached to the array where it is recorded. A computer uses this information to recreate an image of the infrared source. Engineers can build a detector to sense specific wavelength bands by varying the composition and thickness of the layers.

TIRS isn't the only instrument that will benefit from the QWIP technology, which is especially effective for Earth observation. Jhabvala, who would like to use other R&D funding to ultimately build a 2,000 x 2,000 imaging array and a 512 x 3,000 wide-swath application array, says the technology is applicable to at least one of the National Research Council's proposed decadal-survey missions for Earth science.

It also is being tested for a possible mission to Mars, Jhabvala said. The U.S. Geological Survey (USGS) is interested in one day developing a possible mission that would search for life on Mars, Jhabvala said. "The question is where are the best places to probe? Why not caves? How then do you find caves on Mars?"

To find out, Jhabvala and his research partner, Jut Wynne, a cave biologist with USGS and Northern Arizona University, have set up a QWIP camera near caves in the Mojave Desert to monitor diurnal cave temperatures. The team has shown a clear thermal contrast between the cave opening and the surrounding landscape. Throughout the course of a day, the cave entrance appears cold during sunlight hours and hot at night. "This is exactly the type of thermal signature we might try and locate on the surface of Mars," Jhabvala says.

"This information would be collected and then a determination could be made remotely to send a probe to this location and hunt for any signs of life. We will continue to refine our data-collection and reduction capability over the next few years as the QWIP technology evolves and our experience increases with more field tests." ◆

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Looking for Life on Mars — Just a Little Closer to Home

The Mars Science Laboratory (MSL) is expected to touch down on the Martian surface in 2012 to assess if Mars was in the past, or is today, capable of supporting life. But in a sense the search already has begun — just a little closer to home.

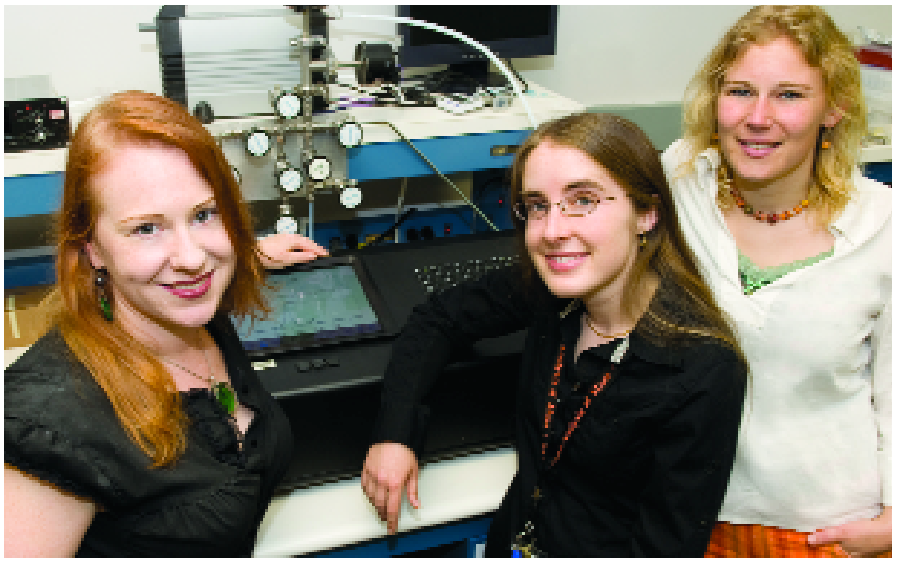

Photo Credit: Bill Hrybck

Scientists Jennifer Stern, Amy McAdam, and Inge ten Kate are traveling to Norway in August to test data-gathering techniques and instruments in preparation for a Mars mission carrying the Goddard-developed Sample Analysis at Mars instrument suite.

In August, three Goddard scientists who are helping develop the Sample Analysis at Mars (SAM) instrument suite — one of 11 instruments flying on MSL — will test data-gathering techniques and instruments at three sites in Svalbard, Norway, an island above the Arctic Circle that closely resembles the environment found on Mars. When SAM begins operations on the red planet in a couple years, it will search for carbon compounds, including methane, which are associated with life. It also will explore ways that the Martian atmosphere creates and destroys them.

The Goddard contingent is participating in the Arctic Mars Analog Svalbard Expedition, an international project sponsored by The Carnegie Institution of Washington, NASA, and several other international academic and research organizations. During this particular trip, scientists will deploy instruments at three sites — methane seeps at Knorringfjellet, a sediment outcrop near Ny Ålesund, and carbonate-encrusted volcanic vents at Sigurdfjellet — and operate them remotely, much like an actual mission to Mars.

"We'll be able to simulate some of the experiments we're doing on SAM to test our systems, verify, and validate some of the data we'll be getting," said Jennifer Stern, who is taking a Cavity Ringdown Spectrometer, a commercial instrument she modified in part with Goddard Internal Research and Development (IRAD) program funding.

Like SAM's Tunable Laser Spectrometer, Stern's instrument will measure the isotopic composition of carbonates that form in the presence of water and carbon dioxide. Knowing the isotopic ratios of carbon compounds can help scientists determine whether biological or abiotic processes were responsible for their formation.

An Evolved Gas Analysis Mass Spectrometer provided by Amy McAdam will support Stern's investigation and will emulate some of the tasks SAM will perform on Mars. Instead of examining carbon isotopes, McAdam's instrument will characterize rock and soil samples by monitoring the compounds released as they are heated to high temperatures. In particular, it will look for organic materials trapped within the samples.

And scientist Inge ten Kate is taking the Goddard-developed Volatile Analysis by Pyrolysis of Regolith (VAPoR), a miniaturized version of SAM that originally was developed for lunar exploration, but is suitable for investigating other airless bodies and those with thin atmospheres. The portable field instrument, developed in part with IRAD funding, will analyze gases in the atmosphere as well as vapors that are produced when its onboard oven heats soil and rock samples to at least 1,200° C (2,192° F). The oven is capable of reaching higher temperatures than SAM. The measurements could help scientists determine whether organic compounds exist in the sample.

Eventually, the instrument will carry a time-of-flight mass spectrometer, also developed in part with IRAD funding. The new spectrometer contains nano-constructed components that could make it more capable and much smaller than its predecessors. Ultimately, the VAPoR team hopes to win a future planetary mission, and the field campaign in Norway is designed to demonstrate the instrument's capabilities.

"I think it's a really cool opportunity," McAdam said. "The entire campaign will simulate what a real rover team would do." ◆

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NASA Technology Critical to 16-Year-Old Sailor's Rescue

When 30-foot waves damaged her 40-foot sloop while she sailed the Indian Ocean 2,000 miles west of Australia in early June, 16-year-old Amy Sutherland activated her distress beacon and set in motion an international search and rescue operation that ultimately resulted in her safe return to California.

Behind the headlines, however, was a little known fact: NASA technology saved her life.

Her dramatic rescue could not have happened without a multitude of technologies developed by Goddard for the Search and Rescue Satellite-Aided Tracking (SARSAT) program, managed by the National Oceanic and Atmospheric Administration (NOAA) as part of an international program, said NASA Search and Rescue Mission Manager David Affens. "This case is more interesting than most because we contributed to every aspect of it."

When Sutherland activated her distress beacon — a personal handheld locator developed by Microwave Monolithics under a Goddard-managed Small Business Innovation Research program award — the device transmitted an emergency signal to a geosynchrous-orbiting satellite equipped with Goddard-developed repeater technology. The satellite then relayed the signal via the SARSAT network to the U.S. Eight minutes after Sutherland manually activated her beacon, the U.S. Coast Guard's Pacific Area Command in Alameda, California, contacted her worried parents using information she provided when she registered her beacon with NOAA. And less than an hour later, two NOAA weather satellites, launched by a Goddard team, used NASA technology to pinpoint her location.

Ultimately, a French fishing vessel, which was 400 miles from her location when the distress signal was detected, was directed to her location to perform the rescue.

New Search and Rescue System Planned

Now Affens's organization, along with NOAA, the Coast Guard, and the Air Force, are working to develop a new and improved search and rescue system, called the Distress Alerting Satellite System (DASS). The next-generation system will more quickly detect and locate distress signals generated by the emergency beacons. That's because NASA plans to install the repeaters on the Global Positioning System (GPS), a constellation of 24 spacecraft operating in mid-Earth orbit, and not weather satellites where they currently reside.

Identify Distress Signals Faster

"A few years ago, we looked to see how we could improve the system and we concluded that the international search and rescue community would benefit from new technology installed on GPS," Affens said. "We would be able to identify distress signals faster and with a greater level of precision." The improved response time is made possible because of GPS coverage. With GPS, at least four satellites are in view of any location worldwide. Almost instantly, processing of the signal can begin to determine the precise location of the person in distress.

Although the current system is effective, as evidenced by Sutherland's rescue and those of 28,000 others worldwide since the system became operational in the mid-1980s, a weather satellite may not be in position to pick up a distress signal for up to two hours after a user activates the beacon. Furthermore, weather satellites in geostationary orbit cannot independently locate a beacon unless it contains a navigation receiver that encodes and transmits its position — a capability not offered on most units. "Right now, it can take an hour or more before we can even act on a signal," said Mickey Fitzmaurice, a space systems engineer for NOAA's SARSAT program.

The new GPS-based system is now being tested. Currently, nine GPS satellites are flying the proof-of-concept technology and an additional 12 are planned. Goddard is testing the technology before transitioning to a final system after 2015, which will be deployed on the Air Force's Block III GPS satellites. "The bottom-line here is that within one minute, we'll know where the distress signals come from," Fitzmaurice said. "It is the future." ◆

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Goddard Tech Trends

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